

Nonlinearity in Oscillatory Flows over Sand Ripple

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Abstract

In this report, We investigated the nonlinear phenomena in the study of flow dynamics of velocity component. In our studies, we observed nonlinear term in the vertical component of velocity by vittori et al [7] The time series simulation of vertical component which increases with Reynold stress value. We developed direct numerical simulation under two dimensional grid system to study the flow dynamics and vorticity parameter. Flow pattern and flow dynamics near wavy boundary wall in the vicinity of ripple bottom was readdressed under direct numerical simulation(DNS) framework. Both horizontal and vertical component of fluid velocity were studied under pulsating force of flow. Vorticity is calculated under complex framework by taking into higher order interaction term. we tried to carry out similar simulation with same particle ejection in the viscous bed using DNS simulation for pulsating flow. Our focus was to observe particle motion using DNS simulation and study the particle phase under vortex structures formed here.

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I. INTRODUCTION

Many observations were made concerning a complex bed form pattern in the vicinity of offshore region. Temporal chaos in fluid turbulence is the symptomatic of spatial chaos. The chaos in turbulence can be studied by many numerical approaches.

As widely discussed, the chaotic pattern is detected in turbulence both for fixed geometric configuration increasing the flow Reynolds number and for fixed characteristic of oscillatory flow increasing the amplitude of the wall waviness. From an analysis of the The tide driven current in the offshore region is the m major source sediment transport in beach areas. The current deflects toward the crests due to increase in bottom friction with a decreasing water depth. Hence the cross ridge velocity increases to satisfy continuity whereas the along ridge velocity decreases owing to increase of bottom friction. Huthnance was the first to present a mathematical description using simple flow model. He used a simplified version of depth average shallow water equation with a power law relationship for sediment transport corrected for downhill gravitational transport.

and turbulence pattern under complex bed-fluid interaction mechanism. In fact, vast sea water(both offshore and near shore) is not clear Underneath sea with complex bed form having ripple is observed occasionally. [?]

Indeed many observations were made concerning a complex bed form pattern in the vicinity of offshore region. The bottom topography is indeed very complex in nature. These ripples are formed due to oscillatory nature of turbulence flow over sand bed form in a complex manner where the bottom topography often takes form of The chaotic phenomena related to turbulence studies were observed by [4] brick or tile pattern depending on the complexity of the bed-fluid interaction under turbulence flow. Flow becomes more complex near the shore region where the flow due to oscillatory nature affects the ripple formation. It is believed that waves are mainly responsible for sediment transport where currents carry the entrained sediments away. Field observations focussing tide driven region indicate the presence of symmetrical and asymmetrical waves with crest almost perpendicular to the direction of main current and characterized by wavelengths of few hundred metres. In this region, full understanding of turbulence with oscillatory flow is needed to understand the sediment flow. Turbulent fluctuations due to oscillatory nature of flow are usually confined within a thin oscillating boundary layer. This situation makes very difficult to take experimental data accurately in this region which makes sometimes the interpretation of data controversial. There are different numerical approaches to study these problems such as Reynolds Averaged Navier Stokes Equation(RANS), 'Direct Numerical Simulation(DNS). LES model is based on solving Navier Stokes equation with large eddy function and small eddies are neglected in this calculation. It well known for its simplicity and low computer cost but can not give more insight in the complex phenomena. On the other hand, Reynolds Averaged Navier Stokes Equation alsoo known as RANS model is based on On the other hand, DNS simulation does not involve any turbulence model but uses unsteady flow using grid system that are sufficiently fine to resolve all scales of motion. A first attempt to explain the mechanism of this flow made by Hara an Mei [3] who developed a three dimensional model investigating the stability of Stokes layer induced by sea wave. The associated steady state along the ripple surface showed a tendency to accumulate sediment particle in various pattern. B Blondeaux & Vittori [5] tried to model sand ripple based on brick pattern form on the basis of three dimensional simulation model. They studied three dimensional vortex structure in the oscillatory form of flow under two dimensional ripple bed. In both cases,

a unidirectional oscillatory flow is considered and fluid particles are considered on top of the bottom boundary to oscillate to and fro. Ripple at sea bed affects the sediment transport rate and cause additional energy dissipation enhancing mixing in the vicinity of ripple. However the detail knowledge of the flow structure and the dynamics of vortex structure generated by flow separation is not clear in this region. Recently Scandura & Blondeaux [?] studied by means of numerical simulations, the flow induced by wavy wall under uniform oscillatory motion. They observed in the simulation that velocity is periodic under weak flow and vorticity is shed just above the crest which has a tendency for pitchfork bifurcation above critical value of velocity.

In our numerical simulation, we tried to readdress the problem of chaos in velocity and vorticity field and observed similar bifurcation at critical value of velocity. Our direct numerical simulation is based on finite difference scheme for oscillatory flow of fluid and we observe development of bifurcation in the normal and streamline flow component which increases with u_0 . The nonlinearity nature of the vertical component of the velocity also shows similar pattern.

II. FORMULATION OF THE PROBLEM

The problem was formulated in the following way, We consider incompressible fluid of density ρ and kinematic viscosity ν induced close to a wavy wall by a uniform oscillating pressure gradient. We define Cartesian orthogonal coordinate We start with Navier Stokes equation for an incompressible fluid flow in rectangular (x, y, z) coordinates. We also consider wall profile described parametrically by the relationship

$$y = -\frac{h}{2}[\cos(k\xi) + \sum_{n=1}^N c_n \cos(\gamma_n)] \quad (1)$$

$$x = \xi + \frac{h}{2}[\sin(k\xi) + \sum_{n=1}^N c_n \sin(\gamma_n)] \quad (2)$$

where $k = \frac{2\pi}{l}$ is the wavenumber of the waviness. ξ is a dummy variable and $\gamma_n = nk\xi + \phi_n$.

$$\frac{\partial u}{\partial t} + \mathbf{u} \cdot \nabla u = -\frac{1}{\rho} \frac{\partial p}{\partial x} + \nu \nabla^2 u + F^{(x)} \quad (3)$$

$$\frac{\partial w}{\partial t} + \mathbf{u} \cdot \nabla w = -\frac{1}{\rho} \frac{\partial p}{\partial z} + \nu \nabla^2 w \quad (4)$$

$$\nabla \cdot \mathbf{u} = 0 \quad (5)$$

For Direct numerical simulation algorithm, we choose collocated, nonstaggered grid system. The algorithm we

$$-\frac{1}{\rho} \frac{\partial p}{\partial y} + \nu \nabla^2 v \quad (6)$$

$$\frac{\partial w}{\partial t} + \mathbf{u} \cdot \nabla w = -\frac{1}{\rho} \frac{\partial p}{\partial z} + \nu \nabla^2 v \quad (7)$$

$$\nabla \cdot \mathbf{u} = 0 \quad (8)$$

where the field velocities (u, v, w) are along (x, y, z) directions respectively.

For the sediment particle, the basic equation is controlled by spherical particle moving under gravity in viscous fluid.

A. Discussion and Conclusion of the Results

We consider the flow of an incompressible viscous fluid of density ρ and kinematic viscosity ν induced close to wavy wall by a uniform oscillating pressure gradient. The nonlinear fluctuation and periodicity was observed here for velocity component both in streamline and vertical flow field. The nonlinearity increases with u_o above the threshold value. When the shear stress experienced by the interface between the flowing fluid and the resting particles is low, the flow is unable to entrain the particles lying on the bed, which then remains immobile. As the shear stress increases,

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